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(71) Applicant(s)
Roke Manor Research Limited
(Incorporated in the United Kingdom)
Roke Manor, Old Salisbury Lane, ROMSEY,
Hampshire, SO51 0ZN, United Kingdom

(72) Inventor(s)
George Malcolm Swift Joynes

(74) Agent and/or Address for Service
Margaret D Mackett
Siemens Group Services Limited, Intellectual
Property Department, Siemens House, Oldbury,
BRACKNELL, Berks, RG12 8FZ, United Kingdom

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(54) Abstract Title
Acoustic location systems

(57) An acoustic location system (28) comprises an acoustic signal generator (42) for generating acoustic signals, a plurality of acoustic sensors (30,32,34,36) which operate to detect acoustic signals reflected by a target body (4) and to generate data signals representative thereof. The data signals are fed to a data processor (38) which is coupled to the acoustic sensors (30,32,34,36) by connectors (40). The data processor (38) identifies valid data by associating signals from said sensors according to their angle of arrival, amplitude and timing, before determining the location of the target body (4) from an intersection of loci. The loci are representative of hypothetical locations of the target body (4) determined in accordance with a time of flight of the acoustic signals from the acoustic signal generator (42) to the acoustic signals (30,32,34,36) reflected via the target body (4).
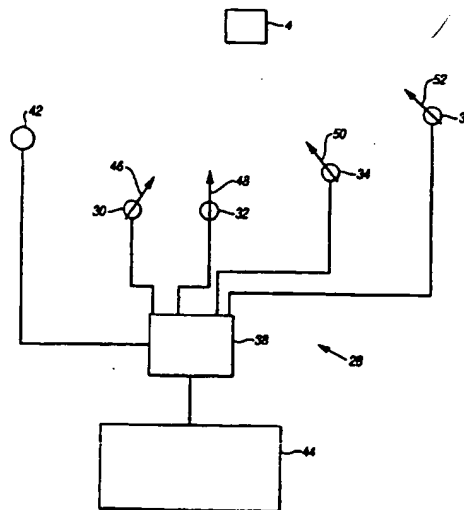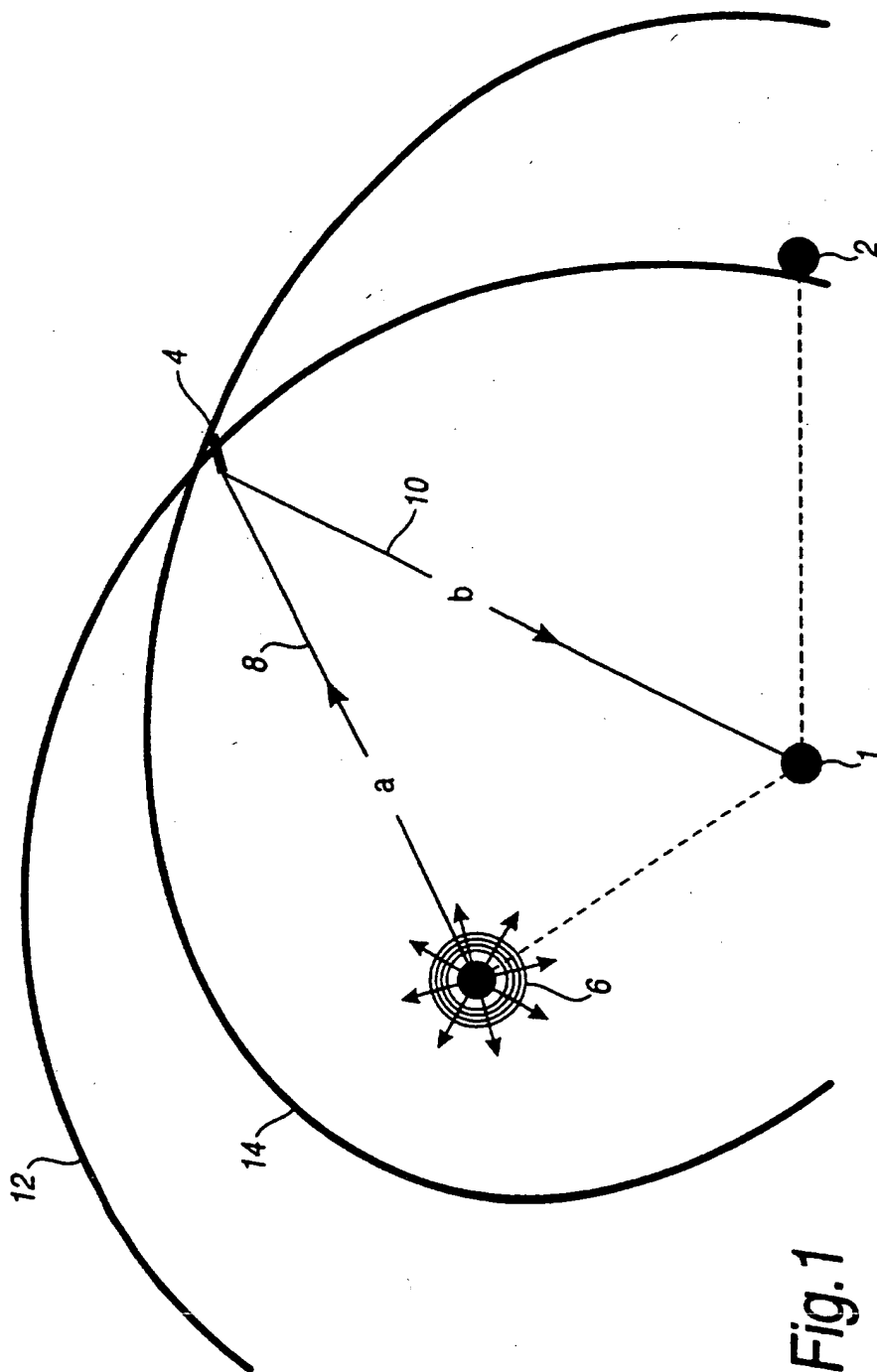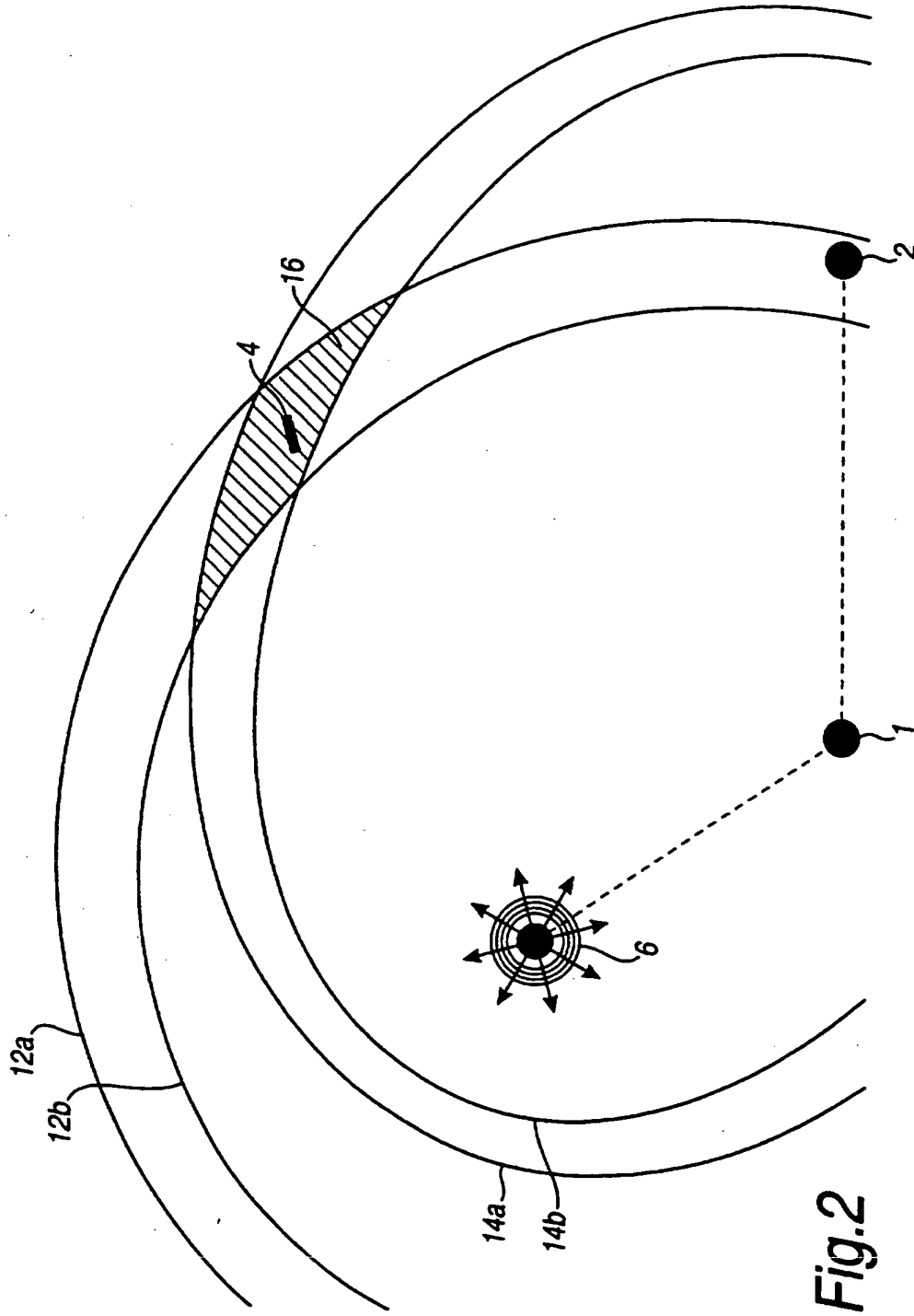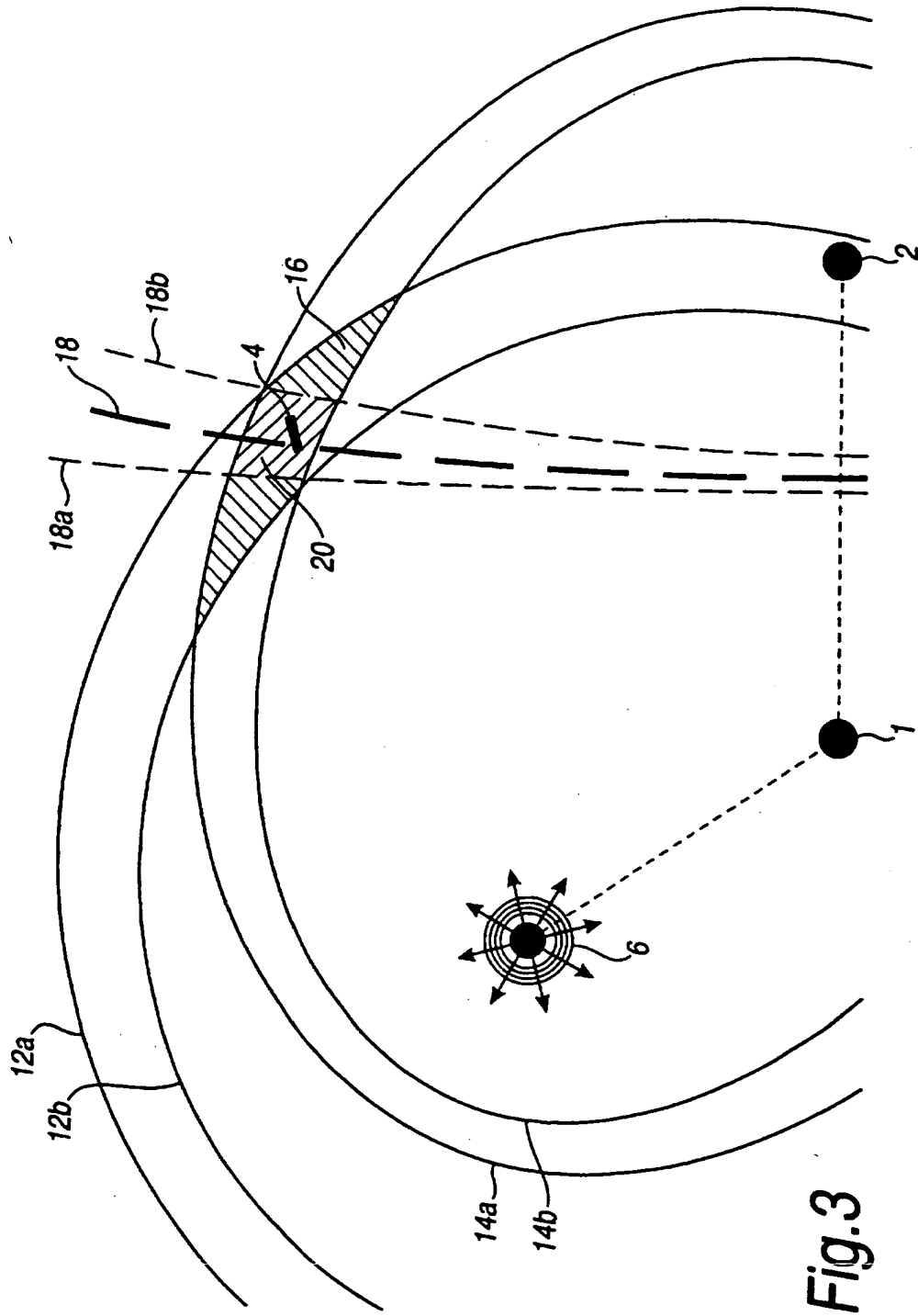
Fig.7

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1

12a

12b

16

4
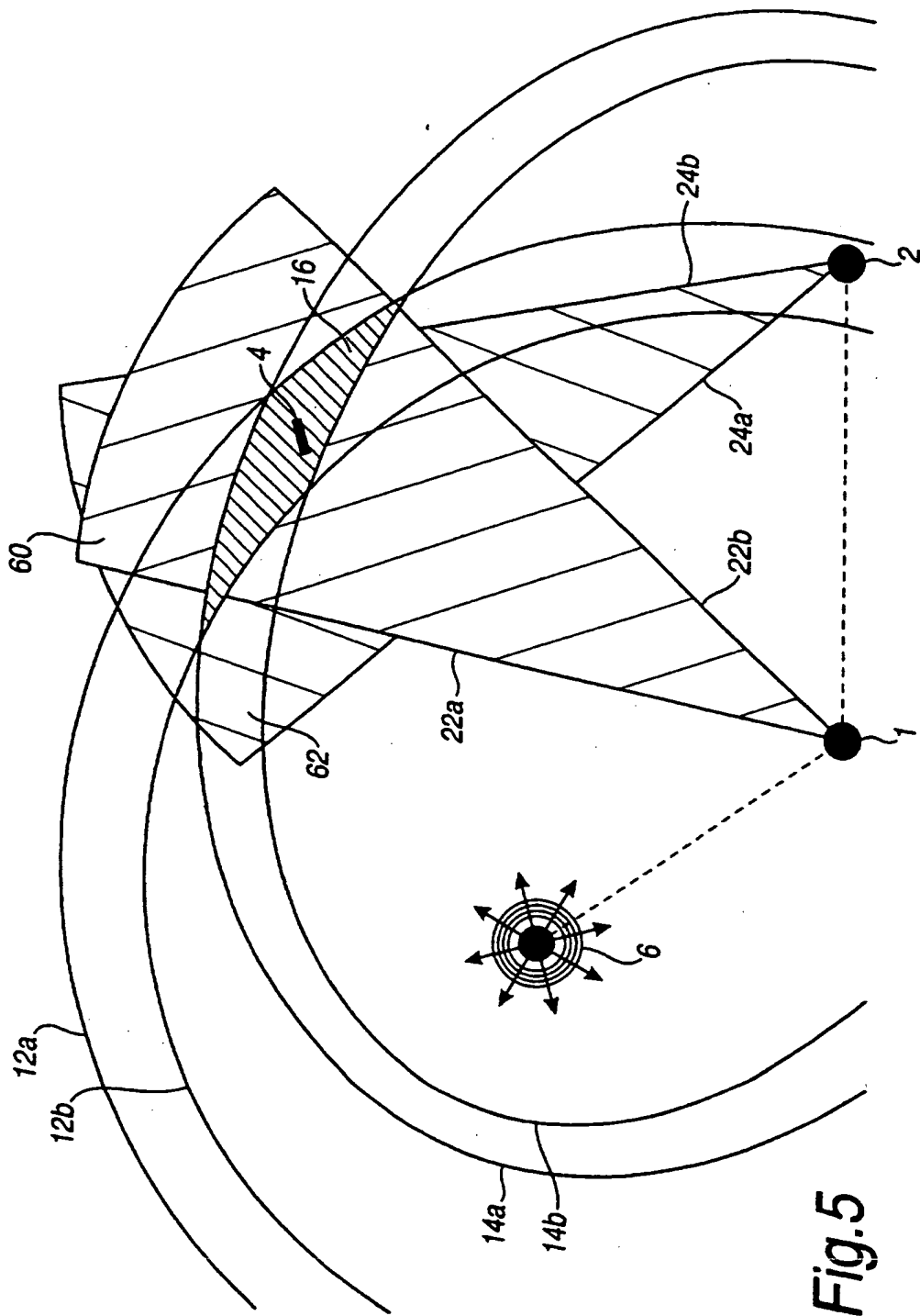
14a

14b

2

1

6

Fig.2

Fig.3

Fig.4

Fig.5

Fig.6

Fig.7

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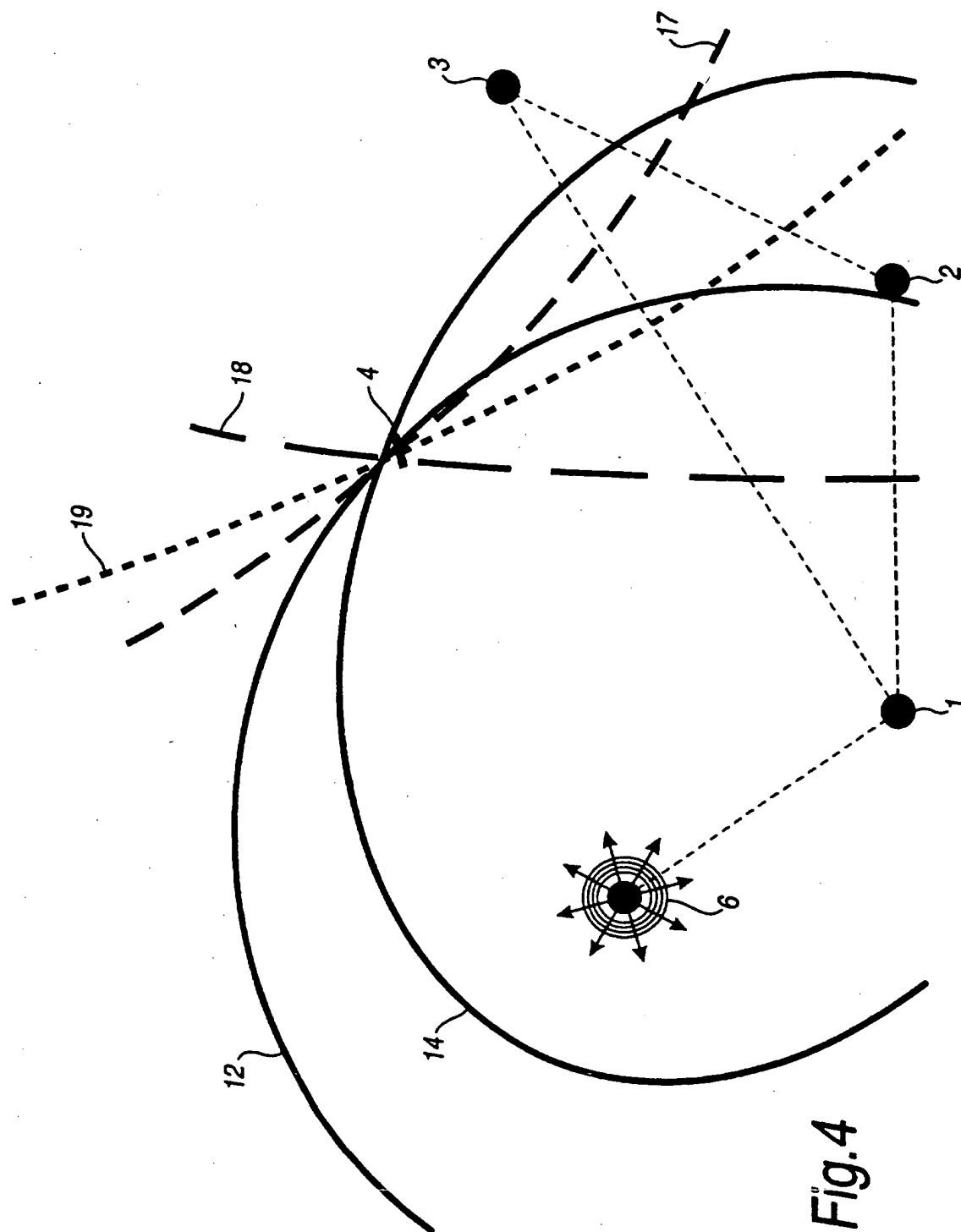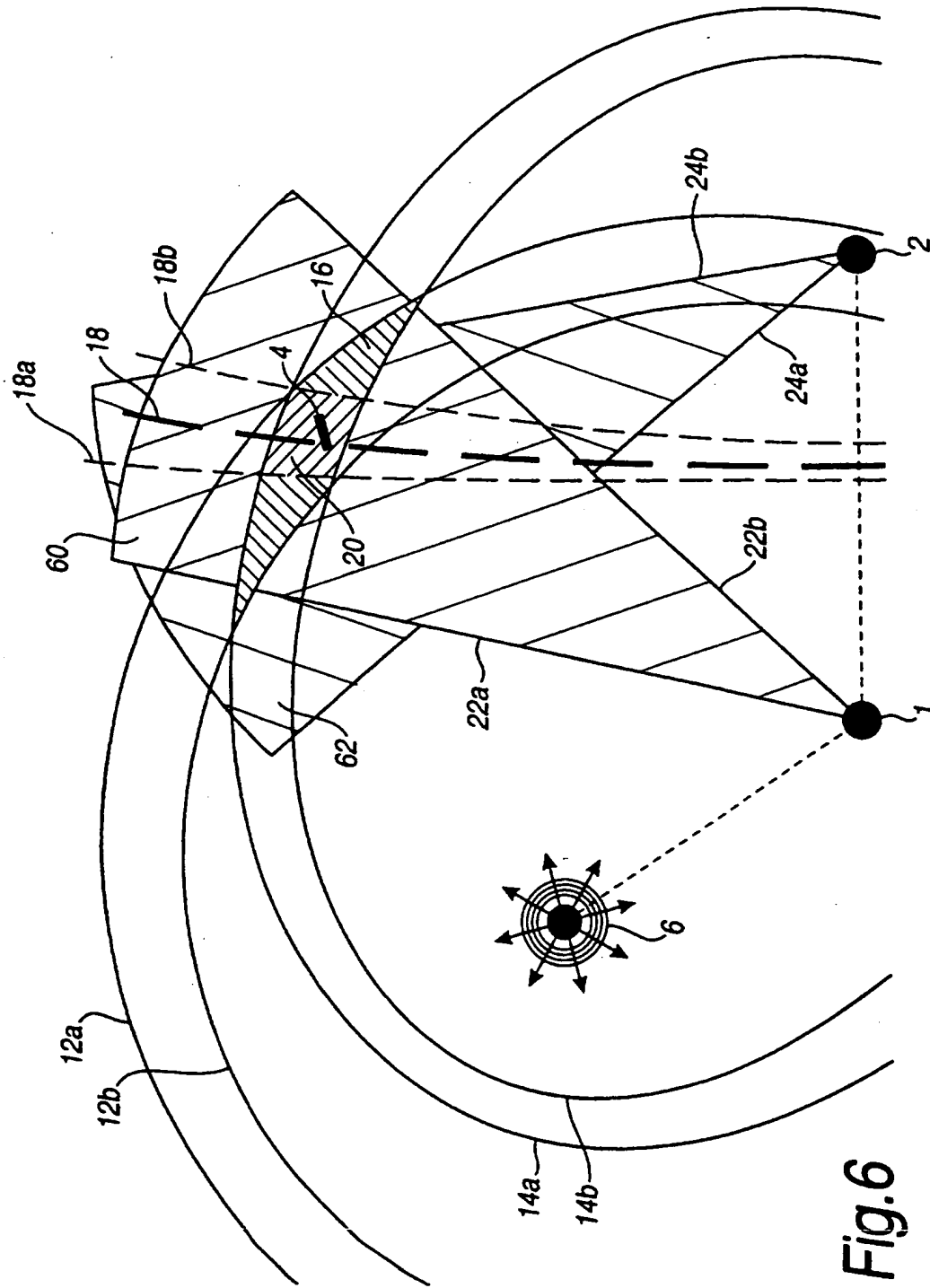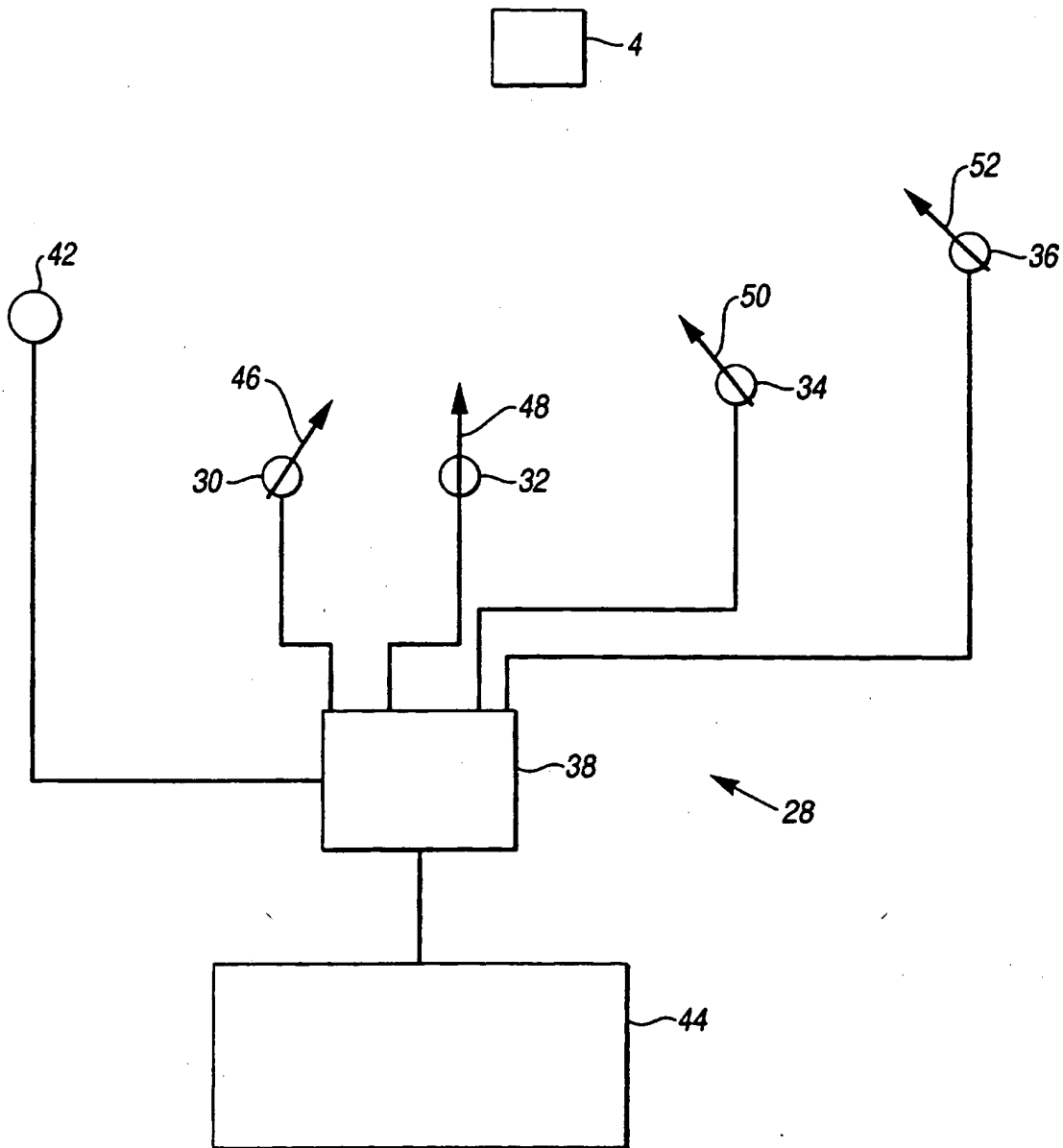
ACOUSTIC LOCATION SYSTEMS

The present invention relates to acoustic location systems which operate to locate targets from acoustic signals emitted from or reflected by those targets. In particular, but not exclusively, the present invention relates to acoustic location systems for locating targets which are at least partially submerged in water. Such systems are generally known as sonar systems.

The terms 'acoustic' or 'sound' as used herein refer to and include acoustic signals or sounds which are both audible and inaudible to the human or animal ear.

Sonar systems are provided with at least one acoustic sensor, known as a hydrophone, which serves to detect acoustic signals or sounds emitted or reflected by a target body. A single sensor may comprise a small local array of hydrophones. Sonar systems may be termed as either 'active' or 'passive'. In a 'passive' sonar system, hydrophones of the system are arranged to listen for emissions of acoustic signals radiated from the target body. The acoustic signals may be either continuous wave signals or pulsed sound signals. In an 'active' sonar system, on the other hand, the system is provided with an acoustic generator or source which generates an acoustic signal at a predetermined time, and the hydrophones are arranged to detect the acoustic signals reflected from the target body. The acoustic generator may also generate a plurality of pulsed signals or a continuous signal. The term 'acoustic generator' is intended to encompass any means for producing acoustic signals including any source outside the direct control of the system, but is not intended to encompass the target body itself.

In known 'active' sonar systems, the location of a target is determined from a time of flight of acoustic signals generated by an acoustic signal

generator and reflected by the target body. With a predetermined knowledge of the speed of the acoustic signals in water, a sonar system comprising one generator and one hydrophone may determine the total distance travelled by the acoustic signals, that is, the distance from the generator to the target body

5 and a distance from the target body to a hydrophone in the system. However, the sonar system is unable to determine the distribution of this total distance between that part of the distance from the acoustic signal generator to the target body, and that part from the target body to the hydrophone. As such, the sonar system may only determine a locus representative of a hypothesis

10 of possible locations of the target body in dependence upon portions of the total distance associated with the distance between the acoustic signal and the target body, and that from the target body to the hydrophone. However, by providing the sonar system with a plurality of hydrophones, and by determining a locus representative of a hypothesis of possible locations of the

15 target body for each of the plurality of hydrophones, it is possible to determine the location of the target body from an intersection of each of the loci thereby locating the target body with respect to the hydrophones.

The method of detecting the location of the target with respect to a plurality of hydrophones of a sonar system generally requires that the

20 hydrophones be separated by a substantial distance relative to the target body so that the loci representative of the hypothesis of possible locations of the target body with respect to each hydrophone intersect with a substantially perpendicular relationship. However, typically the spatial displacement of the hydrophones with respect to each other may be small with respect to a

25 distance to the target body. Furthermore as a result of differences in the speed of sound and inaccuracies in detecting acoustic signals generated by the acoustic source, there exist certain errors in determining the loci

representative of the possible location of the target body. As such, there is a problem in improving the probability of being able to detect a target body unambiguously, and the accuracy with which a target body may be located by a sonar system.

5 It is an object of the present invention to provide a method of increasing the probability of detecting a target body and reducing the probability of detecting phantom target bodies and false alarms, whilst increasing the accuracy with which a sonar system may detect a target body.

According to the present invention, there is provided a method of
10 locating a target body in a medium using acoustic signals received therefrom at a plurality of acoustic sensors, the method comprising the step of associating acoustic signals received from the target body at each of the acoustic sensors with one another.

In this way, acoustic signals received from each of the plurality of
15 acoustic sensors are processed by associating signals received at respective acoustic sensors, acoustic signals reflected by other artefacts within a volume associated with the target body being eliminated.

The acoustic signals received at each acoustic sensor from the target body may be associated by means of a predetermined or adaptable range of
20 angles of arrival at each sensor. Additionally or alternatively, the acoustic signals received at each acoustic sensor from the target body may be associated by means of a predetermined or adaptable time window for time of arrival of the signals at each sensor. Furthermore, the acoustic signals received at one of the acoustic sensors from the target body may also be
25 associated by means of an amplitude correlation with respect time. This correlation may only be possible where the type of acoustic signal permits,

for example, where synthesised waveforms are produced from an active source or generator.

In a preferred embodiment of the present invention, the method further comprises optimising the location of the target body using associated

5 sets of data corresponding to the received acoustic signals.

The method further includes determining a plurality of time differences between when the acoustic signals are received at one of the acoustic sensors and when the acoustic signals are received at another one of the acoustic sensors. The method additionally comprises generating a

10 plurality of loci representative of the plurality of time differences and determining a location of the target body from an intersection of the plurality of loci.

By determining the time difference between the time of arrival of the acoustic signals at first and second acoustic sensors, the sonar system is

15 provided with a further hypothesis on the location of the target body which may be represented as a locus. The intersection of this locus with the loci determined from the range estimate at each of the acoustic sensors, provides a more accurate estimate of the location of the target body relative to the acoustic sensors.

20 Determining a time difference between a time when acoustic signals emitted by a target body are received at a first acoustic sensor from a time when the acoustic signals are received at a second acoustic sensor, a first locus of possible locations of the target body may be estimated. By calculating a second time difference locus of possible locations of a target

25 body from a difference between a time when the acoustic signals were received at a third and fourth of the plurality of acoustic sensors, the location

of the target body may be determined from the intersection of the first and second difference loci.

In an 'active' sonar system, the method further includes generating at least one acoustic signal at a predetermined or previously unknown location in the medium, and receiving acoustic signals reflected from the target body towards the acoustic sensors.

By controlling the generation of the acoustic signals and correlating the signals received at each acoustic sensor with the generated signal, a further means of discriminating the location of the target body is provided.

The time at which the acoustic signals are generated by the acoustic generator may be unknown, although a distance of the acoustic signal generator from the acoustic sensors may be known. The method of locating the target body may include determining a time when the acoustic signals are generated in accordance with a time of flight of signals from the acoustic generator to the acoustic sensors.

In accordance with a further aspect of the present invention, there is provided an acoustic location system for determining the location of a target body in a medium, the system comprising:- a plurality of acoustic sensors for receiving acoustic signals reflected from the target body and for generating data signals indicative of the received acoustic signals; and processing means for processing the data signals, the processing means including means for associating the acoustic signals received from the target body at each of the acoustic sensors with one another.

The term 'acoustic sensor' is intended to include a single sensor comprising a single detector unit or a single sensor comprising a small local array of detector units.

For a better understanding of the present invention reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1 illustrates an arrangement for detecting a target body using two acoustic sensors and shows the loci of possible target locations;

Figure 2 is similar to Figure 1, and illustrates the effect of errors due to timing on the loci of possible target locations;

Figure 3 is similar to Figure 2, and further illustrates the effect of including the hyperbola representing a time of arrival difference between the two sensors;

Figure 4 illustrates an arrangement for detecting a target body using three acoustic sensors and including hyperbolae representing time of arrival differences between pairs of the three sensors;

Figure 5 is similar to Figure 2, and illustrates the effect of angle of arrival determination at each sensor;

Figure 6 is similar to Figure 5, and further including a hyperbola representing the time of arrival difference between the two sensors;

Figure 7 is a block diagram of a sonar system in accordance with the present invention.

For clarity, the following description makes the assumption that the sensors, generators and target bodies illustrated in the Figures lie in the same plane. However, it will readily be appreciated to a person skilled in that art that, in practice, there may be differences in the actual depths of each of these components, and variations in the characteristics of the medium in which these components are located which must be accounted for.

Detection of a target body using a sonar system from time delays in receiving acoustic signals at two acoustic sensors will now be described with reference to Figure 1. Figure 1 provides an example sonar system

comprising two acoustic sensors 1, 2 which are used to detect and locate a position of target 4 from acoustic signals generated by an acoustic signal generator 6. In this example embodiment, the target body 4 is a vessel submerged in water, and the acoustic sensors 1, 2 comprise small arrays of

5   hydrophones.

However, it will be appreciated by those skilled in the art that the present invention also finds application in detecting bodies immersed in any medium which provides a means for propagating acoustic signals.

Moreover, in the present example, the number of acoustic sensors 1, 2

10   may be increased so as to improve the accuracy and reliability with which the target body is located.

Detection of the target body 4 is determined from measuring a time of flight of a sound impulse generated by the acoustic generator 6. The acoustic generator 6 may be, for example, an explosion. Alternatively, the acoustic

15   generator 6 may be an emitter of a pulse or a sequence that allows unambiguous determination of elapsed time, for example, by generating a series of pulses according to spread spectrum principles. After an emission of sound from the acoustic generator 6, a time of flight for the sound pulse to travel from the generator 6 to the target body 4 and then to the sensors 1, 2 is

20   measured for each of the sensors 1, 2.

In Figure 1, the path between the generator 6 and the sensor 1 via the target body 4 is illustrated by lines 8 and 10 which are representative of the path taken by the sound impulse. With knowledge of the speed of sound in water, and the time taken for the sound to travel from the generator 6 to the

25   sensor 1, the total distance travelled by the sound impulse on a path between the generator 6 and the sensor 1, reflected by the target body 4, is calculated. So, for example, if the time taken to travel between the generator 6, and the

sensor 1, via target body 4, is T_1, then the total distance travelled by the sound is calculated from multiplying the speed of sound in water S_w by the time T_1, that is, the distance $= S_w \times T_1$. It will readily be appreciated that the value of S_w is an average value and the local speed of sound may vary at
5   different points along the path taken by the sound impulse.

In Figure 1, the distance between the generator 6 and a possible location of a target body 4 is generally designated as 'a', whereas the distance between the possible location of the target body 4 and the sensor 1 is generally designated as 'b'. Therefore, it is possible to write:

10     $a + b = S_w \times T_1$.

However, since the distances 'a' and 'b' are unknown, the target body may lie on an elliptical locus representative of the possible combinations of distances 'a' and 'b', such that the equation is still satisfied. This is represented in Figure 1 by the locus 12.

15   By performing a similar calculation for the sensor 2, it is possible to generate a second locus 14 corresponding to the time taken for impulsive sound to travel from the generator 6 to the sensor 2 via the target body 4.

Therefore, it will be appreciated that the location of the target body 4 with respect to the sensors 1, 2 can be determined from an intersection
20   between the locus 12 associated with sensor 1 and locus 14 associated with sensor 2.

Although the target body may be located with respect to the sensors 1, 2 using from the intersection of the loci 12, 14, errors caused by fluctuations in the speed of sound in water, and measurement inaccuracies serve to
25   provided a degree of error and perhaps ambiguity in the location of the target body using the time of flight method hereinbefore described. This situation is illustrated in Figure 2 which shows the sonar system of Figure 1 drawn

with loci 12 and 14 superimposed to show an area 16 within which target body 4 may lie.

In Figure 2, the loci 12 and 14 are now shown as a band of possible loci the boundaries of each band being represented by respective lines 12a,

5   12b, 14a and 14b. These bands are representative of the errors associated with the loci 12, 14 (shown in Figure 1) which serve to increase the uncertainty in the location of the target body 4 within the area 16. The area 16 is therefore representative of an error or, in some cases, an ambiguity in the position of the target body 4 detected by the sonar system. This will

10   hereinafter be referred to as an 'uncertainty area'. It should be noted that the 'uncertainty area' may comprise non-contiguous parts where attempts are mistakenly made to combine sounds from different targets. This leads to ambiguities, rather than errors, in the detection of the target body.

However, an improvement in the accuracy with which the location of

15   the target body 4 may be determined is provided by a further step in the detection process. By subtracting the time taken for the impulsive sound from the generator 6 to arrive at each of the sensors 1, 2, it is possible to generate a further locus representative of a hypothesis for the position of the target body 4 with respect to the sensors 1, 2. This further locus, a hyperbola,

20   is generated from the difference in time of arrival of the impulsive sound at the sensors 1, 2 respectively. This is shown in Figure 3 where the broken line 18 is representative of the time difference locus. Effectively, the time difference locus 18 is representative of an amount by which the target body 4 must be closer to sensor 2 than sensor 1. (It will be appreciated that it may be

25   the case that sensor 1 is closer to the target body 4 than sensor 2. In this case, the time difference locus will adjusted accordingly.)

By superimposing the hyperbola for the location of the target body 4 with respect to the sensors 1, 2 determined from this time difference, the improvement in the resolution of the location of the target body may be achieved by a further intersection with the range loci 12, 14 in their bands

5   12a, 12b, 14a, 14b. Thus, part of the 'uncertainty area' 16 in which the target body 4 must lie is shown by the shaded area 20 representative of a further band of loci bounded by lines 18a, 18b which are representative of possible ambiguities in the time difference locus 18 resulting from errors in detection. The 'uncertainty area' has therefore been reduced by this new step in the

10   method of location.

As may be appreciated, where a sonar system is provided with more than two sensors, a time of arrival difference locus may be determined for each combination of pairs of sensors. In Figure 4, for example, a third sensor 3 is shown. As such, a second time of arrival difference locus 17 may be

15   determined in accordance with a difference in the time of arrival of acoustic signals at the second and third sensors 2, 3 (sensor 3 being closer to the target body 4 than sensor 2). Furthermore, a further time of arrival difference locus 19 may be determined in accordance with a difference in the time of arrival of acoustic signals at the first and third sensors 1, 3 (sensor 3 being closer to

20   the target body 4 than sensor 1). Therefore, a location of the target body 4 may be determined from sounds emitted by the target body from an intersection of the time difference loci 17, 18, 19.

It is possible to improve the process of target location, particularly when using impulsive sources, by adopting the following multi-stage

25   technique:-

(i)   Data from an array of sensors are used to compute angles and times of arrival of acoustic signals at each sensor. Each sensor may have

only a relatively poor angular resolution, because of the nature of the waveforms emitted by the impulsive source and the dimensions of the sensor itself. However, this poor resolution may still be compatible with the sorting process that occurs next.

5   (ii)   A front-end sorting process, termed 'associative processing', is carried out to associate the incoming signals at each of the sensors, in angle, time and amplitude, thereby to combine them together in sets for further processing.

        (iii) Associated sets of data are fed to an optimal location algorithm, 10   typically a least mean squares estimator, which combines the times of arrival of the acoustic signals in a way that provides the least error in estimation of the target body location.

        The benefits of this three stage process are:-

        (a)   in some circumstances, it will be possible to reduce the 15   complexity and therefore cost of the sensors (or alternatively to extend their lifetimes);

        (b)   the 'associative processing' enables the system to reject much of the multi-path clutter that otherwise either confuses the operator or prevents the implementation of a fully automatic system; and

20   (c)   use of the whole processing chain should improve the location accuracy.

        In accordance with the present invention, an embodiment of the implementation of the processing discussed above will now be described. In Figure 5, the first step of the multi-stage process is shown. Estimated angles 25   of arrival of the sound impulse at sensors 1, 2 are illustrated by lines 22a, 22b, 24a, 24b which define sectors 60, 62. In this case, it is necessary that each sensor 1, 2 comprise an array of detector units, for example,

hydrophones. By determining an intersection between the sectors 60, 62 defined by lines 22a, 22b, 24a, and 24b, it is possible to provide an initial coarse estimate of the location of the target body.

Furthermore, sounds with an angle of arrival outside a predetermined

5   sector may be eliminated from the process of determining the location of the target body as described above. Thus, this correlation of the predicted target body position is used as a pre-filtering process.

Another embodiment for implementing the processing discussed above is to establish 'time windows' for the arrival of the sound impulse at

10   the sensors 1,2. Each 'time window' sets limits within which a correctly associated sound impulse should arrive at the appropriate sensor.

The 'associative processing' step becomes a more powerful tool if both estimated angles of arrival and 'time windows' are implemented together. It will be appreciated that there are several ways in which these two

15   techniques can be combined, but the combination depends on the particular sonar system in which they are being utilised.

At the end of the 'associative processing', data is available as associated sets. An associated set comprises items of data, one from each sensor, which have a high probability of having emanated from the same

20   target body.

As well as errors generated by inaccuracies in measuring time or angular resolution of sound detected by sensors 1, 2, the performance of sonar systems is also affected by noise received at the sensors 1, 2, and sound emissions from unwanted target bodies or artefacts within or near the

25   'uncertainty area' associated with the target body 4.

The last step in the process is to perform an optimal or optimising location algorithm. Such an algorithm might be, for example, a least mean

squares estimator which serves to combine the times of arrival of the acoustic signals and the angle of arrival of the acoustic signals at the sensors 1, 2 so that a mean square error in the location of the target body is minimised. The mean square error algorithm operates to minimise the error associated with

5   each of the methods of locating the target body so that the total mean square error is made as small as possible.

Figure 6 illustrates a preferred embodiment of the present invention which encompasses the techniques described above. In particular, sensors 1, 2, generator 6 and the elliptical loci 12, 14 and their associated error bands

10   12a, 12b, 14a, 14b derived therefrom are shown. In addition, the hyperbola 18 and its associated error band 18a, 18b corresponding to the difference in times of arrival of the acoustic signals at sensors 1, 2 (as described with reference to Figure 3) is shown. Moreover, sectors 60, 62 corresponding to the angles of arrival, described above with reference to Figure 5, are

15   superimposed.

A further discriminator which can be used in 'associative processing' is the amplitude of the acoustic signals received by the sensors. By comparing the received amplitudes from the sensors and referring to a propagation model appropriate to the layout of sensors in the sonar system, it

20   is possible to determine the likelihood that the correct association of events has been made. This improves the confidence level in the associative process.

Thus far, the method of locating the target body 4 with respect to the sensors 1, 2 has been described with respect to an 'active' sonar system in

25   which the target body is located from reflected sounds emitted by an acoustic generator 6 and received at sensors 1, 2. However, it will be appreciated by

those skilled in the art that the techniques described above with respect to an 'active' sonar system may also be used for a 'passive' sonar system.

A sonar system 28 for detecting at least partially submerged vessels is illustrated in a schematic block diagram in Figure 7. In Figure 7, the sonar

5   system 28 comprises four sensors 30, 32, 34, 36, each coupled to a data processor 38 by a plurality of conductors generally shown as 40.

As will readily be appreciated by those skilled in the art, other means may be used instead of the plurality of conductors 40 to convey signals from the sensors 30, 32, 34, 36 to the data processor 38. For example, signals may

10   be conveyed between the sensors 30, 32, 34, 36 and the data processor 38 by a radio communications link or a fibre optic link.

Also coupled to the data processor 38 is an acoustic generator 42. The generator 42 may emit impulsive or continuous wave like sound. Connected to data processor 38 is a synthetic display 44.

15   In operation, the sensors 30, 32, 34, 36 are used to detect acoustic signals received from a target body 4. These sounds may be generated by the acoustic generator 42, if the sonar system is 'active', and reflected by the target body 4 to the sensors 30, 32, 34, 36, or may be emitted by the target body 4 itself, if the sonar system is 'passive'. Alternatively, the sensors 30,

20   32, 34, 36 may receive sounds generated by the generator 42 and reflected by the target body, as well as sounds emitted from the target body in a combination system. Signals representative of these sounds detected by the sensors 30, 32, 34, 36 are thereafter fed to the data processor 38 by conductors 40. The conductors 40 may be radio, recording and subsequent

25   combining or other communication means.

The sensors 30, 32, 34, 36 (each of which comprises an array of detector units) provide angle of arrival sensing means as indicated by

respective arrows 46, 48, 50, 52. It will be appreciated that the angle of arrival sensing means includes a pre-processor (not shown) which processes the outputs from each detector unit in the array to provide the sectors relating to the angle of arrival as discussed above. Alternatively, the pre-processor

5   may form part of the data processor 38.

If the sonar system is operating in an 'active' mode, data processor 38 operates to excite the generator 42 thereby coordinating the generation and detection of acoustic signals reflected from the target body 4. The data processor 38 thereafter serves to perform the target location process in

10   accordance with the following steps:

    (i)   Data produced by each of the sensors 30, 32, 34, 36 representative of the acoustic signals received at each sensor and the angle of arrival of these acoustic signals is fed to data processor 38.

15   (ii)   The data processor 38 performs an 'associative processing' technique as described above wherein the signals received at each sensor 30, 32, 34, 36 are compared in accordance with angle of arrival and time of arrival and a correlation of the change in amplitude of the signals with time thereby eliminating

20   noise and clutter due to unwanted emissions.

    (iii)   The output of the 'associative processing' technique is the associated sets of data.

    (iv)   Loci representative of possible target body positions are determined in accordance with the time taken for sound to travel

25   from the generator 42 to the target body and back to the sensors 30, 32, 34, 36. Intersection of the loci defines an 'uncertainty area' in which the target body 4 lies. (It will readily be

understood that the loci need not be generated, but the data used directly to determine the 'uncertainty area' as defined as location estimators comprising a location point expectation value and a spatial error function.)

5   The 'associative processing' technique in accordance with the present invention reduces the number of potential sets of data corresponding to phantom target body locations that are processed. Phantom target bodies are target locations falsely detected by the sonar system which appear to be present from data provided from the sensors.

10   The locations of possible target bodies determined by the data processor 38 may be displayed on a visual display unit (VDU) 44. Each point in the display can be excited to exhibit an intensity proportional to its strength. The VDU 44 has an intensity decay rate which will enable the display to show evolving activity and movement of target bodies and clutter.

15 This improves an operator's ability to discriminate possible targets from clutter.

    A further addition to the system is to provide the data processor with information representative of the ocean layering and distribution. This can be used to make the velocity of sound spatially dependent and thus increase

20 the accuracy of the location estimate. Furthermore, a data base may be included in the data processor which provides information appertaining to the position of several targets which may be known a priori or inferred. This data base may be used to provide an improvement in the accuracy of target location by eliminating signals generated from these targets during the

25 location process.

    The embodiment of the sonar system described above has a plurality of sensors for detecting sonar signals. As such, it will be appreciated that

such a system may continue to operate to determine the location of a target body even if one or more of the sensors fail.

As will be appreciated by those skilled in the art, various modifications may be made to the embodiment described above whilst still

5 falling within the scope of the present invention. In particular, various combinations of steps of the methods of locating the target body using acoustic signals detected by the sensors may be used to determine different types of target bodies. For example, although the described embodiment relates to an 'active' sonar system, it may also be used with a 'passive' sonar

10 system. Furthermore, the present invention finds application for detecting target bodies located in other media. In such cases, the sensors will naturally be replaced by appropriate acoustic sensors.

It will readily be appreciated that, although the method of the present invention has been described with reference to the generation of loci of

15 possible target body locations, the method can be executed mathematically without the physical generation of the loci.

Moreover, although the ranges of angles of arrival of acoustic signals at each sensor and the time window for time of arrival of those signals at each sensor may be predetermined, it will be appreciated that these values

20 may be adaptable and can be varied in accordance with the detection of a particular target body from a plurality of such bodies in the vicinity of the sonar system.

CLAIMS:

1. A method of locating a target body in a medium using acoustic signals received therefrom at a plurality of acoustic sensors, the method comprising the step of associating acoustic signals received from a target body at each of the acoustic sensors with one another.

2. A method according to claim 1, wherein the acoustic signals received at each acoustic sensor from the target body are associated by means of a predetermined or adaptable range of angles of arrival at each sensor.

3. A method according to claim 1 or 2, wherein the acoustic signals received at each acoustic sensor from the target body are associated by means of a predetermined or adaptable time window for time of arrival of the signals at each sensor.

4. A method according to any one of the preceding claims, wherein the acoustic signals received at one of the acoustic sensors from the target body is associated by means of an amplitude correlation with respect to time.

5. A method according to any one of the preceding claims, further comprising optimising the location of the target body using associated sets of data corresponding to the received acoustic signals.

6. A method according to any one of the preceding claims, further comprising generating for each pair or group of sensors a locus of possible locations of the target body from the received acoustic signals, and

determining an intersection of the loci to provide an indication of the location of the target body.

7.   A method according to any one of the preceding claims, further including determining a plurality of time differences between when acoustic signals are received at one of the acoustic sensors and when acoustic signals are received at another one of the acoustic sensors.

8.   A method according to claim 7, further comprising generating a plurality of loci representative of the plurality of time differences and determining a location of the target body from an intersection of the plurality of loci.

9.   A method according to any one of the preceding claims, further comprising generating at least one acoustic signal at a predetermined or previously unknown location in the medium, and receiving acoustic signals reflected from the target body towards the acoustic sensors.

10.   A method according to claim 9, further comprising controlling the generation of said at least one acoustic signal and correlating acoustic signals received at each acoustic sensor with said generated at least one acoustic signal.

11.   A method according to claim 9, further comprising determining the time at which each acoustic signal is generated in accordance with the time of flight of each acoustic signal from an acoustic generator to the acoustic sensors.

12.   A method according to claim 9, further comprising determining the distance from an acoustic generator to the acoustic sensors in accordance with the time of flight of each acoustic signal from the acoustic generator to the acoustic sensors.

13.   An acoustic location system for determining the location of a target body in a medium, the system comprising:-

a plurality of acoustic sensors for receiving acoustic signals reflected from the target body and for generating data signals indicative of the received acoustic signals; and

processing means for processing the data signals, the processing means including means for associating the acoustic signals received from the target body at each of the acoustic sensors with one another.

14.   A system according to claim 13, further comprising display means coupled to the processing means for displaying a pictorial representation of the location of the target body, the processing means providing display signals corresponding to the data signals for displaying on the display means.

15.   A system according to any one of claims 13 or 14, wherein the processing means stores and provides ancillary data which is included in the display signals.

16.   A system according to any one of claims 13 to 15, wherein the acoustic sensors comprise hydrophones.

17.   A system according to any one of claims 13 to 16, further comprising a sonar system.

18.   A sonar system substantially as hereinbefore described with reference to Figures 1 to 7 of the accompanying drawings.

19.   A method of locating a target body in a medium substantially as hereinbefore described with reference to Figures 1 to 7 of the accompanying drawings.

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

    UK Cl (Ed.P): G1G (GRA)

    Int Cl (Ed.6): G01S 5/22 5/28 15/42

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